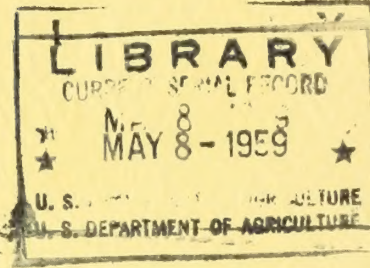


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Lumber Recovery



at a

PONDEROSA PINE SAWMILL IN THE BLACK HILLS

by

E. S. Kotok and C. A. Newport



ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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U. S. DEPARTMENT OF AGRICULTURE
Forest Service

CREDITS

This study was conducted at the request of the Black Hills National Forest and Region 2 of the U. S. Forest Service. Others actively participating were the Newberg Mill, Custer, South Dakota; the College of Forestry and Range Management, Colorado State University; and the Forest Products Laboratory, Madison, Wisconsin.

All field work, including the selection of study trees and delivery to the mill, was done by the Black Hills National Forest. The forest also contributed most of the personnel used in the field phases of the study, including recorders, lumber stackers, and a scaler. Region 2 provided a log grader and a certified lumber grader; the Forest Products Laboratory, a log diagrammer; and the Newberg Mill arranged production to suit the needs of the study.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

The station maintains central headquarters at Fort Collins,
Colorado, in cooperation with Colorado State University

LUMBER RECOVERY

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E. S. Kotok and C. A. Newport^{1/}

- - -

A study to evaluate some of the factors that affect overrun and grade recovery of Black Hills ponderosa pine was conducted in September 1954 at the Newberg Mill, Custer, South Dakota. The study was revised in September 1958 to include results of the analyses of log and tree grades.

Factors studied were site (limestone and nonlimestone), tree size, log size, position of log in the tree, percentage of cull in log, and apparent grade based on visible indicators.

Information on these subjects is needed to improve stumpage appraisal, to show utilization trends, and to guide forest and sawmill management.

METHODS

To sample the range of sizes and quality of trees being harvested in the Black Hills, 243 trees were selected on 2 timber sales. Sample trees were taken from both limestone and nonlimestone sites. These trees were numbered, recorded by d.b.h., and by estimated number of logs to the nearest 8-foot length. Then they were felled and bucked into 613 logs. All logs were numbered to identify the tree and position in the tree. Thus, every log could be analyzed not only on the basis of its own size and character, but also on the basis of the tree and stand in which it grew. All merchantable logs produced from the sample trees were used in the study. This gave an assortment of quality from barely merchantable (33.3 percent sound) to 100 percent sound. Top diameters inside bark ranged from 7 to 22 inches.

^{1/} At the time the report was prepared, E. S. Kotok was technologist in Forest Utilization Research at the Rocky Mountain Forest and Range Experiment Station. He is now chief, Division of Forest Utilization Research at the Intermountain Forest and Range Experiment Station. C. A. Newport was associate professor of Forest Management and Utilization, School of Forestry, Colorado State University. He is now project leader, Ponderosa Pine Log Grade Project at the California Forest and Range Experiment Station.

At the sawmill each log was scaled by standard Forest Service methods, ^{2/} diagrammed for visible defects, and assigned a tentative log grade according to the Modified Region 5 Log Grades shown on page 13. They were later regraded on the basis of log diagrams by the Region 6 Ponderosa Pine Grading Rules, page 14. During manufacture, boards from each log were identified by log number and graded by a certified lumber grader. Board tally for each log was recorded by grade, thickness, length, and width.

The cut of 2 half-day runs, representing 28 percent of the total lumber tally or 11,000 board-feet was stacked and air dried. After being seasoned the sample was surfaced, regraded, and scaled again. Losses resulting from seasoning were computed.

RESULTS

Overrun

When logs are converted to lumber, generally there is a difference between the net log scale and actual lumber tally. This difference is called overrun or underrun, depending on whether the volume of lumber exceeds or is less than the net log scale. The principal factors that cause it to vary are log size, log rule used, sawing practices, and scaling proficiency.

In this study, the net log scale of the 613 study logs was 29,200 board-feet, based on Scribner's Decimal C log rule. The volume of lumber recovered, or lumber tally was 39,386 board-feet. This difference of 10,186 board-feet represents an overrun of 34.9 percent.

Table 1 shows the log scale, lumber tally, and overrun as found on the two sites.

A 34.9 percent overrun is considered high for the area. National forest personnel use about 25 percent in timber appraisals. Operators' reports vary from 15 to 25 percent. The large overrun is perhaps attributable to a number of factors associated with the sawing practices followed by the mill. Most important of these is the production of 6-foot lumber. Normally 8 feet is considered the

^{2/} U. S. Forest Service. National Forest Scaling Handbook. 101 pp., illus. 1941.

Table 1. --Percentage of overrun on the two sites

Scale and tally	Limestone site		Nonlimestone site		Both sites	
	(278 logs)		(335 logs)		(613 logs)	
	Scale	Overrun	Scale	Overrun	Scale	Overrun
	Bd. -ft.	Percent	Bd. -ft.	Percent	Bd. -ft.	Percent
Gross log scale	15,730		19,020		34,750	
Net log scale	14,050		15,150		29,200	
Lumber tally:						
All lengths	18,855	34.2	20,531	35.5	39,386	34.9
Excluding						
6-ft. lumber	17,741	26.3	18,941	25.0	36,682	25.6
Excluding 6-ft.						
& 8-ft. lumber	15,778	12.3	16,478	8.8	32,256	10.5

minimum length, and most mills follow this practice. Sawing 6-foot lengths uses more of the log's taper and thus increases the recovery. In this study, 2,704 board feet, or 7 percent, of the total lumber volume was in 6-foot lumber.

Another factor that apparently contributed to the recovery was the large proportion of dimension lumber produced. Forty-one percent of the production was in form of dimension; the regional average for pine mills is reported to be about 18 percent. Cutting of dimension reduces the number of saw cuts and increases the volume accordingly. Telford^{3/} found that each 1/32-inch reduction in saw kerf increased the lumber yield by about 2-1/2 percent.

Analyses were made to determine the relationship between overrun and various log or tree characteristics. The ultimate objective was to describe overrun as a function of tree d.b.h., a factor that would be valuable to timber cruisers and evaluation specialists. Unfortunately, because of differences in local volume tables and the variation in lumber recovery from trees of equal diameter, no correlation between overrun and tree d.b.h. was possible.

Regression analyses failed to show any measurable influence on overrun due to differences in site, log length, log position, or apparent log grade.

^{3/} Telford, C. J. Small Sawmill Operator's Manual. U. S. Dept. Agr. Agr. Handb. 27, 121 pp., illus. 1952.

Regression analyses did show that a significant correlation existed between gross log volume and lumber tally. The use of log volumes eliminated factors of diameter and length. The equation was developed:

$$y = 1.0064 x + 13.69 \quad \begin{array}{l} (x = \text{gross Scribner log volume;} \\ y = \text{lumber tally}) \end{array}$$

From the application of this equation, it was shown that the average overrun for logs ranging from 7 to 22 inches in diameter and from 10 to 16 feet in length equaled 13.69 board-feet, or approximately 14 board-feet per log. Therefore, a log containing 14 board-feet log scale (Scribner) would probably produce 28 board-feet of lumber, or 100 percent overrun. Similarly, a log scaling 140 board-feet would produce 154 board-feet lumber tally, or 10 percent overrun.

When this formula was tested against the data, it was shown that its application to sound logs was valid. It also applied to defective logs when deductions for defect were accurately estimated.

Lumber Grade Recovery (Green Basis)

Grade recoveries of green lumber expressed as a percentage of the total were distributed as shown in table 2. This includes 2,704 board-feet of 6-foot lumber.

Table 2.--Comparison of lumber-grade recovery by sites
(green basis)

Lumber grade :	Limestone :	Nonlimestone :	Both
site :	site :	site :	sites
Percentage of total			
Selects:			
B	0.6	1.7	1.2
C	2.8	5.8	4.4
D	5.7	8.8	7.4
Dimension:			
1	27.9	20.5	24.0
2	14.8	13.6	14.2
3	2.4	3.2	2.8
Commons:			
1	.4	.2	.3
2	11.2	10.8	11.0
3	23.8	23.5	23.6
4	8.7	9.0	8.8
5	1.7	2.9	2.3

Log and Tree Diameter

The effect of log diameter on grade recoveries has been reported in numerous other similar studies. This analysis showed a marked increase in the percentage of select lumber with an increase in log diameter as shown in table 3 and figure 1. As would be expected, the recovery of select-grade lumber was similarly affected by tree d.b.h. Larger trees produced proportionately greater amounts of clear lumber as shown in table 4 and figure 2.

Rot

The soundness of logs affects the percentage of recovery of select lumber. Since most of the rot associated with ponderosa pine is heartrot, the inner or knotty core of the log is primarily affected. Therefore, as the amount of rot increases in the better logs the percentage of select-grade lumber similarly increases. For example, a 16-inch by 16-foot log contains 160 board-feet (Scribner). Suppose that four 1x4's of select grade can be cut from the log -- a total of 21.3 board-feet. If the log is completely sound, selects make up 13.3 percent of the total volume. On the other hand, if say, heartrot calls for a 16 board-foot reduction in net scale, the proportion of selects increases to 14.8 percent of the total. Still greater amounts of heartrot will further increase the proportionate amount of select-grade lumber produced. Defects other than those affecting the inner core of the log would produce the opposite relationship.

Site

There was a marked difference in grade recoveries for the two recognized sites of the Black Hills. As was shown in table 2, lumber from the nonlimestone site was 16.3 percent select grade, but only 9.1 percent of the lumber from the limestone site was of these upper grades. Because the sample of logs drawn from the two sites differed considerably in the distribution and range of size classes, in the distribution of log grades, and in the ratio of net scale to gross scale, it is impossible to attribute the differences in the percent of select-grade recovery to site alone. However, we can conclude from this study that the nonlimestone site in general produces larger and better grade logs, but more of them are defective than on the limestone site.

Table 3. --Effect of log diameter on lumber-grade recovery

Lumber grade	Log diameter inside bark (inches)							
	7.5	9.5	11.5	13.5	15.5	17.5	19.5	21.5
----- Percentage of total -----								
Selects:								
B	0	0	1	2	3	3	3	4
C	1	2	3	5	9	13	17	17
D	2	4	6	8	11	14	15	17
Dimension:								
1	41	36	30	21	8	4	2	1
2	21	17	14	11	10	6	3	2
3	4	4	3	3	3	3	3	2
Commons:								
1	1	1	1	1	1	1	1	1
2	12	11	10	10	9	4	2	2
3	14	20	23	25	27	26	21	16
4	3	4	8	12	16	20	25	27
5	1	1	1	2	3	6	8	11

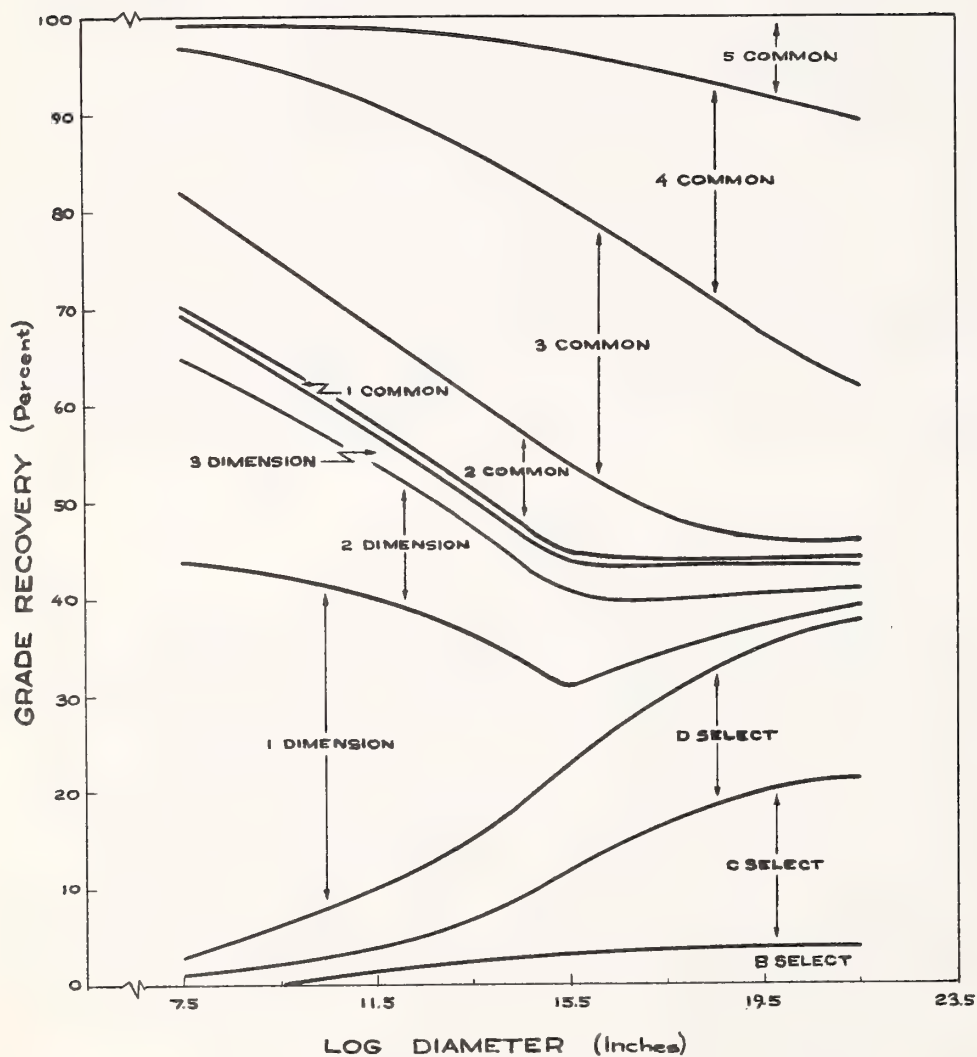


Figure 1. --Effect of log diameter on lumber-grade recovery.

Table 4. --Effect of tree diameter on lumber-grade recovery

Lumber grade	Tree diameter breast height (inches)							
	11.5	13.5	15.5	17.5	19.5	21.5	23.5	25.5
----- Percentage of total -----								
Selects:								
B	0	0	1	1	2	3	3	3
C	2	3	4	6	9	11	13	15
D	5	5	5	8	9	9	10	9
Dimension:								
1	43	36	29	20	10	6	3	2
2	15	15	14	11	10	8	5	4
3	3	2	2	2	2	2	2	2
Commons:								
1	1	1	1	1	1	1	1	1
2	12	15	15	14	11	8	5	3
3	15	16	20	25	30	30	28	23
4	3	5	7	9	12	16	20	24
5	1	2	2	3	4	6	10	14

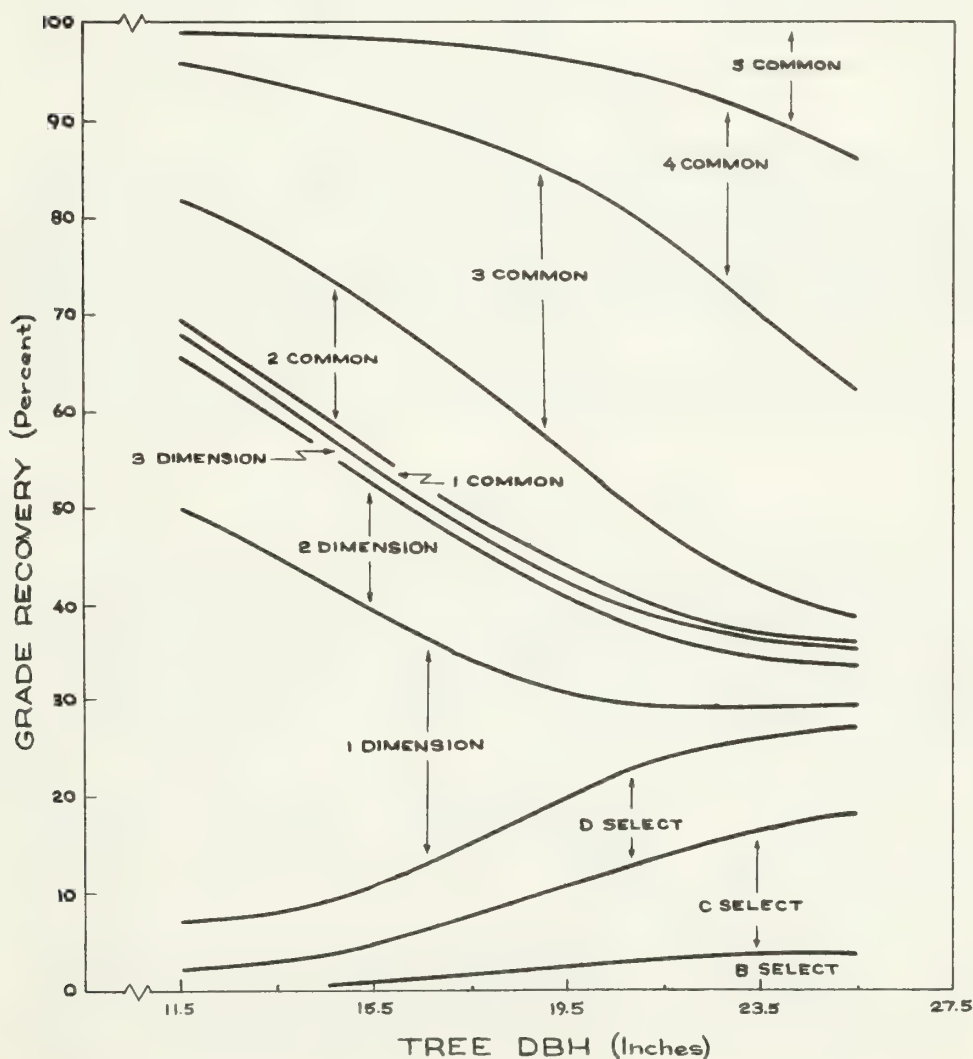


Figure 2. --Effect of tree diameter on lumber-grade recovery.

Log Position in the Tree

As would be expected, proportionately more select-grade lumber came from butt logs than from upper logs. Butt logs yielded almost 3 times as much select lumber as second logs and 10 times as much as top logs.

Dimension Lumber

More than two-fifths of the total output was in 2-inch stock, which contributed to the high recovery. Small ponderosa pine mills frequently have local markets for dimension lumber and adjust their sawing accordingly. Generally, small rough logs are most readily and cheaply converted into dimension-sized lumber.

Select Grades

The recovery of 13.0 percent select grade is higher than that generally reported by Black Hills producers, but -- and this must be emphasized -- such recoveries are possible. It is recognized that some of the select-grade lumber was in 6-foot lengths, a size not always produced by ponderosa pine mills. However, where markets exist for this short lumber, sawmills should take full advantage of improving grade recovery by sawing short boards.

Seasoning Degrade

Degrade after air seasoning during the relatively mild fall months was moderate. There was a 1-percent loss in volume. Lumber was dried to an average of about 15 percent moisture content, planed, and regraded. The original, or green grade, was unknown to the grader.

After volumes and grade distribution of the air-dry sample were adjusted to the all-sample green output, final grades (dry basis) were as shown in table 5.

The drop in select grades was 20 percent for the limestone site and 18 percent for the nonlimestone site. It is safe to assume that the degrade was not influenced by the site of origin.

Table 5. --Lumber-grade recovery by sites (dry basis)

Lumber grade :	Limestone :	Nonlimestone :	Both :	Difference :
:	site :	site :	sites :	for both sites :
:	:	:	:	:(green to dry)
- - - - Percentage of total - - - -				
Selects:				
B	0.2	2.0	1.1	- 0.1
C	2.3	4.4	3.5	- .9
D	4.7	6.3	5.8	- 1.6
Dimension:				
1	28.6	20.8	24.5	+ .5
2	14.4	14.6	14.5	+ .3
3	2.2	1.2	1.7	- 1.1
4	--	.7	.3	+ .3
Commons:				
1	.1	.2	.1	- .1
2	9.1	5.7	7.5	- 3.5
3	21.0	19.1	20.1	- 3.5
4	15.7	20.5	17.8	+ 9.0
5	1.7	4.5	3.1	+ .8

Nothing was learned of the influence of the character and size of a log on the amount of degrade occurring in boards made from it. If the reader wishes to determine the probable dry tally for a specific green grade recovery, he should adjust the green grade volumes by the amount shown in the "difference" column of table 5.

Log Grades

Basis for Quality Index

Before the accuracy of a given log-grading system is determined or before two grading systems are compared, some single dependent variable is needed to replace the numerous interdependent lumber-grade yields. Log-quality index is such a variable. It has been used in a number of log-grade lumber-recovery studies for other species and in other regions. Although the basis of the quality index varies in several past studies, the principles used in its determination are the same.

The quality index for each log in this study was calculated by multiplying the volume yield in each grade by the corresponding lumber-grade value index, totaling these weighted lumber-value indexes, and dividing by the total lumber yield for that log. The lumber-grade value indexes used were based on current local prices and were computed by dividing the actual price of each grade by the price of No. 3 common and multiplying by 100.

Comparison of Two Log-grading Systems

As discussed earlier, each log was graded according to the Modified Region 5 Log Grades and later regraded on the basis of log diagrams by the Region 6 Ponderosa Pine Log Grades as reworded on November 1, 1958. An average log-quality index was determined for each of the grades as provided in the respective rules. Results of the segregation provided by the two grading systems along with the comparable mean quality indexes and variances are shown in table 6.

Table 6. --Comparison of the mean log-grade quality indexes for the modified Region 5 and the Region 6 ponderosa pine log grading systems

Log grade	Mean quality index	Variance of unit quality index	Average recovery volume	Logs
			Bd. -ft.	No.
<u>Modified Region 5 System</u>				
1	166	590	127.8	17
2	143	362	86.4	22
3	124	133	85.6	34
4	113	280	60.6	540
				<u>613</u>
<u>Region 6 System</u>				
1	167	406	97.6	16
2	114	370	59.1	358
3	118	203	72.6	113
4	112	103	67.0	54
5	109	86	74.1	33
6	105	440	65.4	15
				<u>1 589</u>

¹ Diagrams were available for only 589 of the 613 logs.

The modified Region 5 system seems to distinguish logs on the basis of quality index. A statistical test of the differences in mean quality indexes of the adjacent log grades as segregated by this system showed significance at the 1-percent level. The system, however, placed 88 percent of the logs in the poorest grade. This raises a question: Is a system which places so many logs in one classification worthwhile? A classification that places most of the logs in the middle classes would seem more desirable.

The magnitude of the variances of the unit indexes for the Region 6 system is about the same as that for the California system. The distribution of logs in the Region 6 grades is more desirable because it is concentrated in the middle classes. However, this

system as applied, seems to distinguish only two qualities of logs -- grade 1 and others. The quality indexes for grades 2, 3, 4, 5, and 6 indicate only small differences.

This system may have possibilities in field application. Its application to the log diagrams resulted in too many grade 2 logs, and these grade 2 logs varied considerably in unit quality index. Future studies will apply the Region 6 system in the field to make a more valid test.

Tree Grades

The development of a log-grading system is only a step toward the principal objective -- a tree-grading system. In the Newberg study, the position of each log in the tree was recorded so that lumber recovery and quality index could be determined for each tree. The trees were arbitrarily graded into grades 1 through 4, depending upon the grade of the butt log by the modified California system. The variance of the mean tree-quality index was determined for each of these tentative tree grades. Table 7 shows the relationship of these mean quality indexes and a test of the differences among the several grades. The differences are rather small and not significant except for tree grade 1. Therefore, this tentative method of grading trees is not satisfactory.

Table 7. --Comparison of the mean tree-quality indexes for the first tentative system of tree grading (based on Modified Region 5 log grades of the butt log)

Grade	Mean quality index	Variance	Average lumber recovery per tree	Trees
			<u>Bd. -ft.</u>	<u>No.</u>
1	139	594	288	14
2	122	218	206	19
3	118	64	227	27
4	114	365	139	167

Another tentative tree grade was based upon the butt log grade of the Pacific Northwest system. The results are shown in table 8. Although the differences between the mean tree-quality indexes of the first three adjacent log grades is significant at the 1-percent level, the system does not seem to be justified. The distribution of trees in the grades is questionable since the butt logs were graded from the diagrams. More study is needed before this tentative system based on Pacific Northwest butt log grade can be accepted or rejected.

Table 8. --Comparison of the mean tree-quality indexes for the second tentative system of tree grading (based on the Pacific Northwest grade of the butt log)

Grade	Mean quality index	Variance	Average lumber recovery per tree	Trees
			<u>Bd. -ft.</u>	<u>No.</u>
1	143	621	185	16
2	121	260	151	80
3	115	62	185	79
4	109	38	149	43
5	109	34	216	7
6	92	--	84	2

CONCLUSIONS

Results of the study showed that a small circular sawmill operating on Black Hills ponderosa pine can obtain as much as 35 percent overrun. Major contributing factors to the larger than average overrun were the log scale used, the practice of sawing lumber to 6-foot lengths, and to the large percentage (41 percent) of dimension lumber sawed.

The study further indicated that with careful sawing a reasonably high volume (13 percent) of select lumber can be expected. A portion of this relatively large volume of select lumber is undoubtedly attributable to the practice of sawing 6-foot lumber.

The major characteristics, other than log grade, useful in predicting lumber-grade recoveries appear to be log and tree size, log position, and soundness.

Losses resulting from air seasoning were generally small.

Both log-grading systems tested distinguished logs on the basis of quality. As applied, however, neither grading system showed strong justification for use of log grades. Similar results were obtained where the grade of butt logs were assigned as tree grades.

APPENDIX

MODIFIED REGION 5 LOG GRADES (California System)

Grade 1: Select Logs. Minimum diameter 22 inches on small end and practically surface clear. One or two knots near the end of a log over 36 inches d.i.b. are permissible if remainder is surface clear. Smaller logs must be surface clear for the full length. Indication of knots near the surface eliminates logs from this grade as effectively as visible knots or limbs.

Grade 2: Shop Logs. Knots of any size and other blemishes are permissible provided they are so distributed as to produce lumber from which a high percentage of factory cuttings may be obtained. Seventy-five percent or more of the surface should be in clear areas at least 8 feet long and 6 inches or more in width between knots or defects. Logs having 75 percent clear surface, either in length or circumference and 25 percent common surface are included in this grade although they normally do not produce much shop lumber.

Grade 3: High Common. Logs with numerous small or pin knots of the types permissible in the grades of No. 1 and No. 2 common lumber. Knots in pine logs must be 80 percent or more alive or intergrown. This type of log occurs mainly in the tops of thrifty full-crowned trees and close inspection is necessary to insure seeing all dead limbs or knots.

Grade 4: Low Common. Large knotted, coarse logs and logs with numerous small black or dead knots. Lumber produced from this log grade consists mainly of low shop and common.

REGION 6 PONDEROSA PINE LOG GRADES
(Pacific Northwest System)

Grade 1

Clear, smooth logs without indication of any knots near surface.

One pin knot permitted.

Grade 2

- (a) 3 faces clear¹; 1 face knotty.
- (b) Lower 3/4 length clear¹; upper 1/4 few knots.
- (c) Lower 14 feet clear¹; upper 2 feet numerous knots.

¹ 1 pin knot permitted in clear portion.

Grade 3

Fifty percent of total surface in clear areas at least 4 feet long by 1 foot wide.

- Type 1. Knots staggered at least 3 feet apart.
- Type 2. Knots in whorls at least 6 feet apart.
- Type 3. Two faces clear, two rough.
- Type 4. Butt logs 8 feet clear, top 8 feet rough.

Grade 4

High-grade common lumber, numerous knots, sound, close to surface.

Maximum-size knots permitted: 12-inch logs -- 2 inches live,
1 inch dead.
24-inch logs -- 4 inches live,
2 inches dead.

When logs have maximum knot size the average spacing shall be minimum of 2 feet.

Grade 5

Numerous live and dead knots. Maximum knot size permitted.

- Type 1. 12-inch logs -- 4 inches live, 2 inches dead.
24-inch logs -- 5 inches live, 3 inches dead.
36-inch logs -- 6 inches live, 4 inches dead.
- Type 2. One-third log surface in clear areas -- 3 feet by
1 foot.

Grade 6 Logs too rough for all other grades.

